LABORATORY OUTLINES FOR EMBRYOLOGY

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BY

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PHILADELPHIA

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1012 WALNUT STREET

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PREFACE

These outlines were first written for use by students in the large laboratory classes in embryology in Kansas State Agricultural College, and represented the work done (by those classes) during one term (twelve weeks). After they were used for two terms, they were revised, parts rewritten, and some sections added. It is thought that the use of an outline is the simplest means of securing more or less uniformity in the work of the several classes and, at the same time, of encouraging the development of the individuality of both the student and the teacher. The course is not intended as an independent one, but is planned to supplement recitation and lecture work so that the student may obtain by observation a general knowledge of the processes and phenomena of development. The material suggested for use in the course is such that, if it is not already at hand, it may be obtained with a minimum of difficulty. The work is meant to be so arranged that if time does not permit the use of all parts of the outlines, some sections may be omitted and at the same time preserve the continuity of the course.

The author is indebted to various authors for suggestions. Those suggestions have been so modified from time to time that it is scarcely possible to give credit to

any single author for any particular part of the work. The following books, however, have been particularly helpful:

The Development of the Chick, Lillie.
Embryology of the Chick and the Pig, Lillie.
The Development of the Human Body, McMurrich.
Text Book of Embryology, Hertwig-Mark.
Elements of Embryology, Foster & Balfour.
Laboratory Text Book of Embryology, Minot.
A Manual of Histology and Organography, Hill.
Text Book of Zoology, Galloway.
The Cell in Development and Inheritance, Wilson.

The author wishes to express her gratitude to Dr. R. K. Nabours for his criticism of a part of the manuscript and to Dr. Paul S. Welch for reading and criticising the entire manuscript.

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CELL DIVISION

1. All organisms are composed of *cells*. The essential parts of a cell are: (1) The general cell substance, the *cytoplasm*, and (2) a highly differentiated *nucleus*. Most cells have a limiting membrane, the *cell-wall*. Animal cells may have one or more specialized bodies lying near or immediately inside the nucleus, the *centrosome*. The nucleus may be separated from the cytoplasm by a thin membrane, the *nuclear membrane*. The substance of the nucleus is composed of the *chromatin material*, which stains readily with certain dyes and the *achromatin*, which stains less readily. When the cell is in the so-called *resting stage* there is a portion of the chromatin which is larger, more compact, and stains more densely than the other chromatin granules. This is the *chromatin nucleolus*. There may be more than one *nucleolus*.

Draw a cell in the resting stage and label the parts.

2. When division is about to take place, the chromatin elements in the nucleus have the appearance of a coiled thread, the *spireme*. The spireme is not always a continuous thread. The nuclear membrane often disappears at this stage.

Draw a cell in the spireme stage and label the parts.

3. The spireme becomes thicker and finally separates into a number of pieces called *chromosomes*. The chromosomes are of different shapes, depending upon the species of plant or animal. This stage is known as the *astroid stage*. If the cell is an animal cell, the centrosome has divided and the parts of it have migrated to opposite sides of the nucleus. From the centrosomes as centers, radiations extend out through the cell.

Draw a cell in the astroid stage and label all the parts.

The process up to this point is known as the *prophases* or preparation stages.

4. From opposite sides of the nucleus radiations extend across it. These are known as *spindle fibers*. The chromosomes arrange themselves across the spindle midway between the poles. Each chromosome splits longitudinally into halves. This stage is known as the *metaphase* or middle stage.

Draw a cell in the metaphase and label all the parts.

5. One-half of each of the chromosomes passes along the spindle fibers to one pole and the other half to the other pole. When these chromosomes collect around the poles they have the appearance of a double star. This is called the *diastroid stage*. The diastroid stage and the stages in which the chromosomes are between the center of the spindle and the poles are known as the *anaphases*.

Draw a cell with the chromosomes some distance from the poles. Label the parts. Draw a cell in the diastroid stage. Label the parts.

6. After the formation of the *diasters* the chromosomes unite to form a spireme at each pole. From this condition they change into the resting stage or reticular condition. Coincident with the nuclear changes, the cytoplasm may have become constricted into masses, or separated by the formation of a wall perpendicular to the axis of the spindle. The resultant masses are known as daughter cells. The daughter cells may move apart or remain in contact. These final stages are known as the *telophases*.

Draw a telophase in which the chromatin is in a spireme (di-spireme). Label the parts. Draw two daughter cells. Label the parts.

The cell has been followed through the process of division, known as *karyokinesis* or *mitosis*. As a result of this division there are two cells instead of one. Write out the description of the process of mitotic cell division from the resting stage to the daughter cells.

THE SPERMATOZOAN

With the high power objective examine the slide of the pig spermatozoa. Select a single spermatozoan. It is composed of two parts, a large ovoid *head* and a long filamentous *tail*. The anterior part of the head, *the head cap*, does not stain so intensely as the remainder of it. At the base of the head is a part that stains very intensely. This is the *mid-piece*. What is the comparative length of the tail?

Make a drawing of the spermatozoan and label all the parts.

THE EGG

An egg is a cell and has all the essential parts of a cell. However, in the egg, some of the parts have special names. The cell-wall is called the *vitelline membrane;* the nucleus is called the *germinal vesicle;* and the nucleolus is called the *germinal spot.* An egg differs further from most other cells in that it contains yolk material. This yolk material is called *deutoplasm.*

1. Formation of an Egg

Eggs are produced by special glands called *ovaries.* The ovary is covered by a layer of cubical cells called the *germinal epithelium.* It is from this germinal epithelium that the eggs are formed. Early in embryonic life, epithelial buds or strings of epithelial cells grow down into the ovary. Soon these buds lose their connection with the germinal epithelium and form small groups or nests of cells. These groups or nests of cells are known as young *Graafian follicles.* In each follicle one cell takes a central position and is destined to form the *egg* or *ovum.* The egg increases rapidly in size, receiving protection and perhaps nourishment from the cells which surround it. The cells which surround the egg are known as *follicular cells.*

In the section of the cat ovary, find a young Graafian follicle, draw it, and label all the parts.

Only a small number of the young ova ripen and are discharged as mature ova. Those which mature do so

in the following manner: The egg of the young Graafian follicle grows until it is a large spherical cell. The follicular cells remain small and multiply rapidly, forming two layers of cells, between which at one side of the follicle a cavity appears. This cavity is called the *follicular cavity*. As the follicle grows larger, this cavity, which is eccentric in position, is filled with a fluid, the *follicular fluid*. The cells composing the layer of follicular cells, which immediately surround the egg, increase rapidly in number until there are several layers. These cells are known as the *discus proligerus*. The cells external to the follicular cavity are the *stratum granulosum*. There are finally from eight to twelve layers of cells in the stratum granulosum. The discus proligerus is attached to the stratum granulosum. The lighter area immediately outside of the vitelline membrane is the *area pellucida*. The row of cells of the discus proligerus that radiates from the ovum is the *corona radiata*.

When the egg with its surrounding tissue has reached this stage of development it is known as a ripe *Graafian follicle*.

The follicle is enclosed by a capsule composed of two kinds of cells. Those cells which lie nearest the stratum granulosum are more or less spherical, and the others are rather elongate. This capsule is the *theca folliculi*. Surrounding the theca folliculi and forming the substance of the ovary are long, fibrous cells, the *stroma*.

In the section of the cat ovary, find a ripe Graafian follicle and draw it. Label all the parts.

2. Maturation

a. While the egg is in the Graafian follicle the nucleus is large and the chromatin is in the so-called resting condition. The egg is said to be in the growth period. At the end of the growth period it passes through two successive, modified mitotic divisions, the *maturation divisions*. In the eggs of some animals the maturation divisions occur before the egg leaves the ovary, but in others they do not occur until afterward. The Ascaris egg is of the latter type.

On the slide of Ascaris find an egg in the growth period. Draw it and label all the parts.

b. At the end of the growth period, there are half as many chromatin masses as there are somatic chromosomes. In *Ascaris magalocephala bivalens* there are four somatic chromosomes and, therefore, two chromatin masses at the end of the growth period. Each chromatin mass is made up of four parts and is called a *tetrad*. The tetrads arrange themselves on a spindle which is comparatively small and is eccentric in position.

Draw an egg with the tetrads in the middle of the spindle (metaphase) and label all the parts.

c. Each tetrad divides into two parts called *dyads*. One dyad from each tetrad moves to one pole of the spindle and the other dyad moves to the other pole of the spindle.

When the dyads reach the poles the egg divides. The resultant cells are very unequal in size. One cell contains half of the chromatin and little of the cytoplasm.

It is the *first polar body*. The other contains the other half of the chromatin and almost all the cytoplasm. It is the *secondary oöcyte*. The first maturation division is now completed.

Without any change in the form of the chromatin material, a new spindle is formed in the secondary oöcyte. The first polar body may or may not divide.

Draw a secondary oöcyte in a metaphase stage and label all the parts.

d. Each dyad divides into two parts called monads. One monad from each dyad moves to one pole of the spindle and the other one moves to the other pole of the spindle.

Draw a secondary oöcyte in an anaphase stage and label all the parts.

e. When the monads have reached the poles there is a second unequal division of the egg. This division is similar to the first one. The small cell is the *second polar body* and the large one is the *matured ovum.*

Draw a matured ovum showing the second polar body and label all the parts.

3. Fertilization

In Ascaris the spermatozoan penetrates the vitelline membrane before the maturation divisions occur. It may be seen in the cytoplasm of the egg either as an indefinite dark blotch or as unchanged in shape. After maturation is completed the chromatin of the egg changes into the so-called resting condition and is called the

female pronucleus. Coincident with the changes in the egg nucleus, the spermatozoan also changes into the so-called resting stage and is called the *male pronucleus.* These two pronuclei approach each other and fuse to form the *first segmentation nucleus.*

Draw a cell showing the male and female pronuclei. Label all the parts.

4. Cleavage

The amount and distribution of the yolk is correlated with the character of the division of the egg (*segmentation, cleavage*). In eggs, which, for the most part, are small and contain a comparatively small amount of yolk material (*deutoplasm*), the segmentation is complete. That is, the whole egg divides into two daughter cells. This kind of cleavage is known as *total* or *holoblastic cleavage.*

If there is a very small amount of yolk and this yolk almost uniformly distributed throughout the cytoplasm, the daughter cells, in general, are of uniform size. This kind of cleavage is known as *equal cleavage.* Examples of holoblastic equal cleavage are found in the Echinodermata, Amphioxus, and, in general, in the Mammalia. If the yolk is concentrated more at one pole than at the other and yet there is not a large amount of it, the cells resulting from segmentation are unequal in size. This kind of cleavage is known as *unequal cleavage.* Examples of holoblastic unequal cleavage are found in the Cyclostomata and the Amphibia.

In eggs where the amount of yolk is comparatively

large, segmentation is incomplete. This kind of cleavage is called *meroblastic cleavage*. The cytoplasm may be at one pole and the greater part of the egg composed of deutoplasm. In eggs having this distribution of yolk material, the process of segmentation is confined to the region of the cytoplasm and as a result there is formed a cellular disc. This kind of cleavage is called *discoidal cleavage*. Examples of meroblastic discoidal cleavage are found in the fishes, reptiles, and birds. In some eggs the nucleus lies at the center and when it divides the nuclei thus formed migrate to the periphery and thus the yolk becomes surrounded by a layer of cells. This process is called *peripheral cleavage*. Examples of meroblastic peripheral cleavage are found in a number of the Arthropoda.

a. Holoblastic Cleavage

(1) Equal Cleavage

On your slide of the starfish eggs look for a single unfertilized egg. The unfertilized egg may be recognized by its large and comparatively clear nucleus. These eggs are large enough to be seen with the naked eye. Examine one first with the low power and then with the high power. How does the germinal vesicle compare in size with the whole egg? What difference in structure do you observe between the germinal vesicle and the remainder of the egg? Locate the germinal spot.

Draw an egg about one and one-half inches in diameter and label all the parts.

Find an egg which has divided. Can you find a

nucleus in each part? How does the nucleus here differ from the nucleus in the unfertilized egg?

Draw a two-celled, a four-celled, and an eight-celled stage. Label all the parts. Make the drawing one and one-half inches in diameter.

(2) Unequal Cleavage

Examine a frog's egg that has not divided. One part of the egg is dark and the other part is light. The dark part of the egg is the *animal pole;* the light part is the *vegetative pole.* Is the pigment confined entirely to one part of the egg?

Draw a lateral view of an unsegmented egg and label the parts. Make the drawing about an inch and a half in diameter. Shade in the pigmented part.

Find a two-celled stage. How has the division plane divided the egg with reference to the light and dark portions? Is there any difference in the depth of the segmentation furrows? How do you account for it?

Draw a two-celled stage, lateral view. Label parts.

Study a four-celled stage. What is the relation of the second cleavage plane to the first cleavage plane? To the polls of the egg? How do the cells compare in size?

Draw a four-celled stage, view from the animal pole. Label the parts.

Study an eight-celled stage. What is the relation of the third cleavage plane to the other two cleavage planes? To the polls of the egg? What is the comparative size of the cells?

Draw an eight-celled stage, lateral view. Label the parts.

Examine further stages of division. What is the relative size of the cells in the dark and light hemispheres? What is the relative number?

Examine an egg in a many-celled stage. With a sharp scalpel or razor split the egg into halves through the poles. What is in the center of the egg? How many layers of cells are there? When an egg has divided until there are many cells and these cells are arranged in a single layer so as to form a hollow sphere, it is called the *blastula stage.* The cavity in the center of the sphere is the *segmentation cavity.*

Draw a section through a blastula and label the parts.

Examine an egg which has a small indentation on one side. Where is this indentation with reference to the poles? With a sharp scalpel or razor split the egg into halves through this indentation. How are the hemispheres of this egg different from the hemispheres of the blastula stage? What is the form of the segmentation cavity here? How many layers of cells are there? The cells at one pole divide more rapidly than they do at the other pole, which results in the folding in of the cells at one pole. Which pole? This process is known as *gastrulation,* and the stage is known as the *gastrula stage.* The indentation, or the cavity thus formed, is called the *archenteron* or *primitive gut cavity.* The opening of the archenteron to the outside is called the *blastopore.*

Draw a section of a gastrula and label the parts.

5. The Hen's Egg

a. A Raw Egg

Crack slightly the broad end of a hen's egg. Carefully pick off a small portion of the shell. Notice that beneath the shell there is a white leathery tissue. This is called the *shell membrane.* How many layers are there in the shell membrane? If the egg is not perfectly fresh, there will be a space at this end of the egg. This is called the *air-chamber.* Where is the air-chamber with reference to the shell and the membrane? Immediately beneath the shell membrane is the colorless albumen, the *white of the egg.* Pour the egg out into a saucer. Examine a piece of the shell with the dissecting microscope. Notice that it is filled with very small holes. What is the function of these holes? Notice that the white is not all of the same consistency. What is the location of the more fluid part? From the opposite sides of the colored part of the egg, the *yolk*, extend two twisted chords called the *chalazæ* (hail stones). Are they attached to the yolk? Are they attached to the shell?

The yolk is enclosed in the *vitelline membrane.* What other name could be applied to the vitelline membrane? If the egg has been fertilized, there will be at a point on the surface of the yolk, lying immediately underneath the vitelline membrane, a small white disc about 4 m.m. in diameter. This is the *blastoderm.* If the egg has not been fertilized, this spot will be much smaller. It is the nucleus and cytoplasm of the cell. The blastoderm is composed of a layer of cells. The yolk, as in all eggs, is for the nourishment of the developing embryo.

Draw the egg as you see it in the saucer. Label the parts.

Put a drop of the yolk on a slide, add a little water, and examine it with the microscope. What is the appearance of the yolk granules? Are they uniform in size?

Draw some of the yolk.

b. **A Hard-boiled Egg**

Break the shell of a hard-boiled egg and remove without breaking the white. Observe, again, the air-chamber and the character of the shell and the shell-membrane. Try to peel off the white in thin layers. It will be seen that the white is arranged in the form of a spiral. What is the direction of the spiral? Where is the apex of the spiral? Peel off all the white. Usually the vitelline membrane is also taken off from the yolk with the white. Observe the vitelline membrane.

On one part of the yolk there is a disc that is lighter in color than the remainder of the surface of the yolk. This disc is called the "*nucleus of Pander.*" With a sharp knife or razor cut through the "nucleus of Pander" in such a way as to divide the yolk into two hemispheres. If the egg is fresh, it will be seen that the "nucleus of Pander" is connected by means of a narrow neck to a central portion of the egg composed of similar material. This is lighter in color and is more liquid than the other yolk. It is composed of the so-called *white-yolk*. The darker yolk material is called *yellow yolk*. It will be noticed that there are alternate layers of white yolk and yellow yolk. How many layers are there? Which

layers are the thicker? Which forms the greater part of the yolk, the yellow or the white yolk?

Draw the yolk hemisphere and shade in the yellow yolk. Label the parts.

c. An Egg Incubated Three Days—Live Embryo

Open the large end of an egg that has been incubated at least three days. Notice that in whatever position you turn the egg the embryo is on top. Pour the egg into a dish containing normal salt solution which is about milk warm. How much of the yolk is covered by the blastoderm? Notice that immediately surrounding the embryo is a light area. This is called the *area pellucida.* That part of the blastoderm extending beyond the area pellucida is the *area opaca.* The part of the area opaca which contains the blood vessels is the *area vasculosa.* What part of the area opaca is occupied by the area vasculosa? What is the shape of the heart? How fast does it beat? The vessels carrying the blood into the heart are the *vitelline veins.* How many vitelline veins are there? The blood is carried from the embryo to the vascular area by means of the *vitelline arteries.* How many vitelline arteries are there? How does the blood get from the heart into the vitelline arteries? What is the shape of the embryo? What are the differences between the yolk of this egg and the yolk of the fresh egg? What are the differences in the white?

Draw the embryo showing its relation to the yolk. Label the parts.

FIXED AND STAINED EMBRYOS—THE CHICK

1. Embryo with from Three to Six Mesoblastic Somites (Twenty-two to Twenty-four Hours' Incubation)

a. Whole Mount

The darker, more deeply stained part is the *embryo*. The blastoderm extends beyond the embryo. What is the shape of the area pellucida? What is its comparative size? What is the appearance of the area opaca? Is the area vasculosa present?

At the head end of the embryo the blastoderm is folded back under the embryo for a short distance. This fold is called the head-fold. It lifts the head of the embryo from the yolk. On either side of the middle of the embryo, extending longitudinally, are two thickened plates. In the head region they come almost together, but they diverge or spread out nearly flat toward the tail. These thickened plates are called the *neural plates*, and the groove between them is called the *neural groove*. The anterior end of these neural plates will form the *brain* and the remainder will form the *spinal cord*. Lying beneath this neural groove is a thickened cord of cells, called the *notochord*. Does the notochord extend the entire length of the neural groove? Beneath the neural plates, or a little to either side of them, are from three to six pairs of more or less cubical thickenings. These are called the *mesoblastic somites*. How many mesoblastic somites in your embryo? The plate of cells extending tailward from the mesoblastic somites is called the *segmental plate*. With the increase

in development of the embryo more mesoblastic somites will be formed from the segmental plates. The posterior region of the embryo, where the neural plates, the segmental plates, and the notochord are indistinguishable, is the *primitive streak*. Are there any blood vessels?

Make a drawing of the twenty-four-hour whole mount, showing the things described. Label the parts. Make your drawing large enough so that it will almost fill the page.

2. Embryo with from Ten to Sixteen Mesoblastic Somites (Thirty-three to Thirty-eight Hours' Incubation)

a. Whole Mount

What is the shape of the area pellucida? What changes have taken place in the area opaca? The irregular, darkly staining parts of the area opaca are *blood-islands*. This is the beginning of the formation of the *vascular area*. How does the head-fold differ from the head-fold in the twenty-four-hour chick. The neural folds have united in the median line of the body and formed a tube, the *neural tube*. How far back is the neural tube closed? The anterior end of the neural tube is considerably enlarged. This enlarged part is the *fore-brain*. The parts of the fore-brain that project out on either side are the *optic vesicles*. Posterior to the fore-brain is a second enlargement of the neural tube. It is not so large as the fore-brain. This is the *mid-brain*. Posterior to the mid-brain are a few enlargements of the neural tube, which constitute the *hind-brain*. The hind-brain extends to and includes the region of the

third mesoblastic somite. The remainder of the neural tube is the *spinal cord* or *myelon*.

What is the number of the mesoblastic somites? What change has taken place in the primitive streak? Locate the notochord.

The *heart* lies ventral to the hind-brain. What shape is it? What is the comparative size? The two broad tubes which are connected with the posterior end of the heart are the *vitelline veins*. A single tube is connected with the heart at the anterior end. This is the *ventral aorta*. Remember that veins always carry blood toward the heart and arteries carry blood away from the heart.

Make a drawing of the thirty-six hour whole mount and label all the parts.

b. **Transverse Sections**

Sections cut perpendicular to the long axis of the body are *transverse sections*. It is very difficult to cut sections so that they are exactly perpendicular to a given plane. Many of the sections labeled transverse sections are tipped a little to one side or the other. The sections are cut of uniform thickness and arranged in regular order. Those on most of your slides are fifteen microns thick. A micron is one-thousandth of a millimeter. By counting the number of sections in a series the exact length of the embryo may be calculated, provided no sections have been lost. The position of any section may be ascertained by determining its number in the series. In a transverse section of a chick embryo there are found three kinds of cells, and these different kinds of cells are ar-

ranged in layers that are more or less definite. These layers of cells are called *germ layers*. The germ layer lying next to the yolk is composed of rather large, rounded cells. This germ layer is the *endoderm* or *hypoblast*. The one lying next to the shell and farthest away from the yolk is composed of cuboidal and columnar cells, and is called the *ectoderm* or *epiblast*. The one between the ectoderm and the endoderm is composed of irregular cells, and is called *mesoderm* or *mesoblast*. All of the organs of the body are formed from these three germ layers. Most of these organs are differentiated from regions of unequal growth with a consequent folding. If this folding is toward the inner part of the body, it is called an *invagination;* if it is outward from the body, it is called an *evagination*.

The section should be studied with the low power of the microscope unless otherwise indicated. Make outline drawings with hard pencil and use different colors to represent the germ layers. For the sake of uniformity, color the ectoderm blue, the mesoderm red, and the endoderm green. Do not draw the cells. Indicate on your drawing of the whole mount the location of each section.

(1) Through the Fore-brain Showing the Optic Vesicles

The head is free from the blastoderm. How has this separation been brought about? Of what germ layers is the blastoderm composed? The mesoderm is in two layers, one lying next to the ectoderm and the other lying next to the endoderm. The layer of ectoderm with

the mesoderm which lies next to it forms the *somatopleure*, and the endoderm with the mesoderm lying next to it forms the *splanchnopleure*. The space or cavity between the splanchnopleure and the somatopleure is the *body cavity*. If the body cavity is in the embryo, it is called the *embryonic body cavity* or *cœlome*. If it is in the blastoderm and not in the embryo, it is called the *extra-embryonic body cavity*. Is there a cœlome in the section in the region of the fore-brain? The ectoderm forms the outer covering of the head. Is it of uniform thickness? If not, where is it thickest? The *fore-brain* is ectodermal in origin. The *optic vesicles* are evaginations on either side of the fore-brain and are continuous with it. Is the cavity of the fore-brain continuous with the cavities of the optic vesicles? Is there any mesoderm in this section? If so, where? What part is endoderm? It will be observed that the extra-embryonic blood vessels are, for the most part, in the mesoderm of the splanchnopleure.

Draw the section and label all the parts. Color the germ layers.

(2) Through the Middle of the Heart

What is the shape of the heart in cross section? Comparative size? The heart is mesodermal in origin. The inner, thin layer of cells is the *endocardium* and forms the endothelial lining of the heart. The outer, thicker layer is the *myocardium* and forms the muscle of the heart. In the splanchnic layer of mesoderm are numerous holes.

These are cross sections of extra-embryonic blood vessels. Dorsal to the heart is a rather large hole, bounded ventrally by a thick wall and dorsally by a thin one. This is a portion of the fore-gut, the *pharynx*. The pharynx is lined with endoderm. In the median line of the body, dorsal to the pharynx, is a circular mass of cells, the *notochord*. The notochord is endoderm. On each side of the notochord and dorsal to the pharynx is a rather large hole. These are *dorsal aortæ*. Why is there no ventral aorta? All blood vessels are formed in mesoderm. What is the neural tube called in this region? The ectoderm of the outside of the body is continuous with the ectoderm of the blastoderm. Is the cœlome separated from the extra-embryonic body cavity?

Draw the section, label all the parts, and color the germ layers.

(3) Through the Region of the Mesoblastic Somites

The mesoblastic somites are on either side of the neural tube. They are blocks of mesodermal cells which radiate from a common central point. Connecting each mesoblastic somite with the mesoderm of the somatopleure and the splanchnopleure is a neck of cells. This neck of cells is the *intermediate cell mass* or *nephrotome*. The mesodermic layers of the splanchnopleure and the somatopleure are called the *lateral plates*. Compare the size of the dorsal aortæ here with those in section (1).

Draw the section, label all the parts, and color the germ layers.

(4) Through the Primitive Streak

Is the notochord present? Are the dorsal aortæ present? In the median portion of the body the germ layers cannot be distinguished.

Draw the section, label the parts, and color the germ layers. Color black the portion in which the germ layers cannot be distinguished.

c. Reconstructions

(1) Circulatory System

In your sections of the thirty-six-hour chick find the most anterior one which contains the blood vessels. Trace these blood vessels through the remainder of the sections several times. Beginning at the anterior end, sketch in outline all the blood vessels in every third section. Make all your sketches on the same scale and keep them in regular order. Think of these sections placed one upon the top of the other in regular order.

From your sketches make a diagram of the circulatory system and label all the parts.

3. Embryo with from Twenty-four to Twenty-nine Mesoblastic Somites (Forty-four to Forty-eight Hours' Incubation)

a. Whole Mount

It will be observed that a number of striking changes have taken place. These are most noticeable in the head region. In the region of the mid-brain the head has become bent so that the fore-brain and a portion of

the mid-brain form a right angle with the rest of the head. This bend is called the *cephalic flexure*. The head is now completely separated from the blastoderm, and the body, which has been continuous with it on the sides, is partly separated from it by the *lateral folds*, which unite with the head fold. The body has become twisted a short distance back of the region of the heart, so that the head is now lying on its side. Which side? Can you see both optic vesicles? Why? Compare the size of the optic vesicles with that of the fore-brain. What were their relative sizes in the thirty-six-hour chick? The outer part of the optic vesicle has invaginated into the original cavity and has thus formed a cup, the *optic cup*. The walls of this double cup form the two layers of the retina, which may be seen at this time. What is the comparative thickness of these two layers? The place where the rim of the cup does not appear to be continuous is the *choroid fissure*. The outside ectoderm in the region of the optic cup has thickened and formed an invagination into the optic cup. This is the *lens*. It appears as a sphere lying in the optic cup. In the region of the hind-brain is an invagination from the outside ectoderm. This is the *auditory vesicle*.

The heart has elongated more rapidly than the body, consequently it has become twisted upon itself. The vitelline veins are in the lateral folds of the blastoderm. About half way between the vitelline veins and the end of the tail are two blood vessels extending from the embryo into the blastoderm. These are *vitelline arteries*. They carry the blood from the dorsal aortæ to the blastoderm.

Between the hind-brain and the heart in the region of the pharynx are two or three pouches or clefts. These are invaginations from the outside ectoderm. Immediately beneath each pouch is an evagination from the pharynx. These are the *gill-slits* (*visceral clefts* or *pouches*). Each cleft is bounded on either side by a thicker mass. These masses are the arches. They number from the anterior end. The first arch is the *mandibular arch.* The second arch is the *hyoid arch.* The *hyomandibular cleft* is between the mandibular arch and the hyoid arch. It is the first visceral cleft. The other clefts and arches are numbered in order. Ventral to the mandibular arch and beneath the optic vesicle is a pit or invagination from the outside ectoderm. This marks the location of the future mouth and is called the *oral pit.*

How many mesoblastic somites are there? What changes have taken place in the lateral plates? In the primitive streak? Where can you see the notochord?

Draw the forty-eight-hour whole mount and label all the parts.

b. **Transverse Sections**

The region from which is taken the cross section of which you make a drawing, should always be located on your drawing of the whole mount.

(1) Through the Optic Vesicle showing the Lens, the Choroid Fissure, and the Connection between the Optic Vesicle and the Fore-brain (the Optic Stalk)

Because of the cephalic flexure, the plane of this section

passes through the body twice, the fore-brain and the hind-brain. The ventral sides of the two parts lie together. Of what germ layer is the brain formed? The optic vesicle? The lens? The outer covering of the body is ectoderm. The part of the body in which the fore-brain is located is enclosed in two membranes, and the part in which the hind-brain is located is almost, if not entirely, enclosed in these two membranes. The membrane next to the body is the *amnion* and is composed of two layers of cells: an inner layer, the ectoderm, and an outer layer, the mesoderm. On the side next to the yolk is the *yolk sac*, composed of an inner layer of mesodermal cells and an outer layer of endodermal cells. It should be kept in mind that the mesoderm of the yolk sac contains the blood vessels. On the side away from the yolk is the *chorion*, composed of an inner layer of mesodermal cells and an outer layer of ectodermal cells. What is the shape of the optic vesicle? What is the relative thickness of the layers of the optic vesicle? Is the lens a solid mass of cells? Is it connected to the outside ectoderm or has it become separated?

The hind-brain may be distinguished from the fore-brain and the mid-brain on account of its thin roof. What is the shape of the pharynx? The places where the outside ectoderm comes almost in contact with the endoderm of the pharynx are the *gill clefts* or *visceral clefts*. The thickened parts between the visceral clefts are the *gill arches* or *visceral arches*. In each visceral arch is an *aortic arch* which carries blood from the *ventral aorta* to the *dorsal aorta*. Remember that the ventral

aorta is always ventral to the gut and that the dorsal aorta is always dorsal to the gut. In this section, how many ventral aortæ are there? How many dorsal aortæ? Dorsal to the dorsal aorta and to either side of the hind-brain are the *anterior cardinal veins*. The one on the right side is the *right anterior cardinal vein* and the one on the left side is the *left anterior cardinal vein*. Where is the notochord?

Draw the section, color the different germ layers, and label all the parts.

(2) Through the Hind-brain showing the Auditory Vesicles

Identify all the parts found in this section that are found in the previous sections. Ventral to the fore-brain and between it and the pharynx is an evagination from the roof of the oral pit, the *hypophysis*. What is its relation to the brain? Describe the auditory vesicles.

Draw the section, color the different germ layers, and label all the parts.

(3) Through the Posterior Portion of the Heart

The amnion encloses the embryo dorsally, but not ventrally. What part of the central nervous system is here? The mesoblastic somites are no longer thickened blocks of cells, but have differentiated into a somewhat thickened plate of cells, the *myotome* or *muscle-plate*, and a mass of cells that are more or less loosely packed together, the *sclerotome*. What is the size and shape of the gut in this section? Notice the thickened walls of

the *cœlome*, or *body cavity*. How many dorsal aortæ are here? Is the ventral aorta present in this section? Why? Between the body cavity and the outside of the body on either side is a blood vessel. If this blood vessel be traced through the different sections, it will be seen that it connects the cardinal veins with the heart. It is the *duct of Cuvier*. It is formed by the union of the anterior and posterior cardinal veins and empties into the heart near the place where the vitelline veins join the heart. Identify the myocardium and the endocardium.

Draw the section, color the different germ layers, and label all the parts.

(4) Through the Embryo about Half Way between the Heart and the Posterior End

Note the beginning of the folding up of the somatopleure to form the amnion. The point on each side where the lateral fold delimits the embryonic from the extra-embryonic area is the *lateral limiting sulcus*. What is the character of the mesoblastic somites? How have the myotome and sclerotome been formed? On the dorsal surface of the nephrotome is a thick cord of cells with a small hole in it. This is the *Wolffian duct* or *mesonephric duct*. How many dorsal aortæ are there? Are the cardinal veins found in this section? If they are present, they are called the *posterior cardinal veins*.

Draw the section, color the different germ layers, and label all the parts.

c. **Reconstructions**

(1) The Circulatory System

In your sections trace the circulatory system through several times. Make outline drawings of the blood vessels in about every third section. Make all your outline drawings on the same scale, keeping the relative position and shape that are seen in the sections. Keep your drawings in consecutive order.

From your drawings make a diagram of the circulatory system of the forty-eight-hour chick and label all the parts.

What changes have taken place in the circulation between the thirty-six-hour chicken and the forty-eight-hour chicken?

(2) The Central Nervous System

Trace the central nervous system through several times. Make outline drawings of every third section of it. Think of these sections as having a definite thickness and placed one upon the other in regular order.

Make a diagrammatic drawing of the central nervous system and label all the parts.

4. Embryo with from Thirty-five to Thirty-seven Mesoblastic Somites (Sixty-eight to Seventy-two Hours' Incubation)

a. **Whole Mount**

It will be observed that the whole embryo is now lying on its side. There is another bend in the head region. This bend is in the region of the hind-brain and is called

the *nuchal* or *cervical flexure*. Now the region of the hind-brain is the most anterior part of the embryo. The lateral folds have been completed and the tail fold is well formed. In the tail region the digestive tract has begun to fold off from the yolk sac. The posterior part of the digestive tract is called the *hind-gut*. Anterior to the tail-fold on the ventral side of the hind-gut is a bladder-like evagination. This is the *allantois*. The amnion has completely closed, dorsally. The heart is now within the body. Can you trace the twists of the heart? What changes have taken place in the eye? The ear? How many visceral clefts are there? The fore-brain is now composed of two parts: an anterior part composed of two lobes, the *telencephalon*, and a part immediately back of this, the *thalamencephalon*, sometimes called the *diencephalon*. The telencephalon is the rudiment of the *cerebral hemispheres*. Toward the ventral surface of the telencephalon and anterior to the eye is an invagination from the outside ectoderm, the *olfactory pit*. There is a short diverticulum in the roof of the thalamencephalon. This is the *epiphysis*. The mid-brain forms the apex of the cephalic flexure. The mid-brain is the *mesencephalon*. Between the mid-brain and the hind-brain, the central nervous system is considerably narrowed. This narrow part is the *isthmus*. The hind-brain is composed of two parts, the *metencephalon* and the *myelencephalon*. The metencephalon is the most anterior part of the hind-brain and is the rudiment of the cerebellum. The myelencephalon has a thin roof and sides. It is the rudiment of the *medulla oblongata*.

Draw the seventy-two-hour whole mount and label all the parts.

b. Transverse Sections

Study your sections and on your drawing of the whole mount indicate the angle at which they have been cut.

(1) Through the Auditory Vesicle

This section passes through the body twice. Why? Are the two parts of the body separate or continuous? What portions of the central nervous system are shown in each part? What blood vessels are seen in this section? If you cannot tell by looking at only the one section, trace them through and compare with the blood vessels in your sections of the forty-eight-hour chick. Between the floor of the hind-brain and auditory vesicle may be seen the ganglion complex of the seventh and eighth cranial nerves, the *acustico-facialis ganglion.* Above the third aortic arch and ventral to the auditory vesicle is the ganglion of the ninth cranial nerve, the *glosso-pharyngeal ganglion.*

Draw the section, color the different germ layers, and label all the parts.

(2) Through the Optic Vesicle

Your section should be selected so that it will show, if possible, the choroid fissure, the lens, and the optic stalk. What part of the fore-brain is in your section? A part of the hind-brain also may be in the section. What is the relative position of the different parts of the brain?

What is the shape of the lens? Of how many layers of cells is it composed? Identify all the blood vessels. Are the Wolffian ducts present? If present, where are they? What has become of the mesoblastic somites? The fore-gut may have two diverticula, one on either side of the ventral part. These are the *lung-buds*.

Draw the section, color the different germ layers, and label all the parts.

(3) Through the Olfactory Pits

Where are the olfactory pits with reference to the fore-brain? Does this section pass through the mid-brain? Identify all the blood vessels in the section. The rather elongated ventral evagination from the fore-gut is the first liver *diverticulum*. Find the Wolffian ducts. Near the Wolffian ducts are one or more rather thickened tubules. These are the beginnings of the *Wolffian bodies*. It will be seen that the gut and the tissue immediately surrounding it are connected to the body dorsally by a neck of tissue. This neck of tissue is the *dorsal mesentery*. There is also a short neck of tissue ventral to the gut. This is the *ventral mesentery*. The thickenings of the body wall to the side of the posterior part of the body cavity are the *fore-limb buds*.

Draw the section, color the different germ layers, and label all the parts.

(4) Through the Allantois Where it is Connected with the Hind-gut

The allantois is a bladder-like evagination from the ventral side of the posterior part of the hind-gut. What

is its shape in the section? Is the body closed ventrally? What is the shape of the body cavity? Locate the Wolffian ducts. Are the Wolffian bodies in this section? The thickening of the body wall to the sides of the body cavity are the *hind-limb buds*. Does the amnion entirely enclose the body?

Draw the section, color the different germ layers, and label all the parts.

c. **Reconstructions**

(1) **The Alimentary Tract and Its Appendages**

Beginning with the most anterior part, trace the alimentary tract through all the sections. It will be seen that from the most anterior part to the region of the vitelline veins it is an irregular tube. This part of it is the fore-gut. From the fore-gut posteriorly for about a third or a fourth of the length of the embryo the alimentary tract is continuous with the yolk sac. In the posterior part it again forms a tube, the *hind-gut*. The alimentary tract continues to fold off from the yolk sac until the fore-gut and the hind-gut meet. They meet in the posterior part of the duodenum. The most anterior part of the fore-gut, that is, the portion beneath the fore-brain, is comparatively small. This is the *hypophysis*. Suddenly it becomes very large and irregular. The lateral irregularities are the visceral pouches and clefts. How many? Ventral to the second visceral pouch is a long, narrow evagination, the *thyroid gland*. The pharynx becomes flattened laterally to form the *trachea*, and then the lung-buds are given off. Poste-

rior to the lung-buds the gut narrows into the short *œsophagus.* Soon it enlarges somewhat to form the stomach. The ventral evagination of the duodenum is the liver. In the hind-gut the ventral bladder-like evagination, as was mentioned before, is the allantois.

From your study of these sections, reconstruct the alimentary tract and its appendages and make a drawing of it as an opaque object, lateral view.

THE PIG EMBRYO

1. Ten-millimeter Embryo

a. Whole Embryo

Remove all the membranes from a ten-millimeter pig embryo. Examine the external form with the dissecting microscope or the hand lens. It will be noticed that the head is very large in comparison with the body. It forms nearly a right angle with the remainder of the body. This marks the location of the *hind-brain.* Anterior to the hind-brain is an enlarged part which makes a rounded angle. This marks the position of the *mid-brain.* The *fore-brain* is now composed of two rounded lobes, the rudiments of the *cerebral hemispheres.* In the angle ventral to the fore-brain and the mid-brain is the *lens* of the eye surrounded by the edges of the *optic cup.* Extending from the eye ventrally is a depression or groove, the *lachrymal groove.* The lachrymal groove leads to an invagination forming a cup-like pit ventral to the anterior part of the fore-brain. This invagination

is the *olfactory pit*. Caudal to the lachrymal groove and dorsal to the olfactory pit is a thickened part, the *maxillary process* which will form the greater part of the upper jaw. Caudal to this thickening is a second one, the *mandibular* process, which will form the lower jaw. The first *gill cleft* remains as a groove caudad to the mandibular process. This marks the position of the future external auditory meatus. The second, third and fourth gill clefts have disappeared and their remains are marked by a triangular depression, the apex of which is at the ventral terminus of the first gill cleft. This depression is the *cervical sinus*.

Note that the length of the dorsal side of the embryo is three or more times the length of the ventral side. On the dorsal side from the hind-brain terminating in the slender *tail* are a number of segments, the *muscular segments*. On the ventral side of the embryo is the large *umbilical cord*. Its connection with the embryo occupies about one-third of the ventral part of the body or almost all of the ventral surface of the abdominal region proper. Anterior to the umbilical cord the *cardiac region* protrudes ventrally. Between the cardiac region and the muscular segments is a large evagination, the *fore-limb bud*. Between the posterior connection of the umbilical cord to the body and the origin of the tail is another smaller evagination, the *hind-limb bud*. Extending from the fore-limb bud to the hind-limb bud along the curvature of the body is the *milk ridge*.

Draw the whole embryo to scale and label all the parts.

b. **Transverse Sections**

The transverse sections should be parallel to the length of the hind-brain. Indicate on your drawing of the whole embryo the region from which each section is taken.

(1) Through the Anterior Part of the Otocyst

This section passes through the body twice. The hind-brain has a very thin dorsal wall. Its lateral walls have several irregular folds, the *neuromeres.* The *fore-brain* appears as an oval section of the central nervous system. On either side of the body near the hind-brain are the otocysts. The rather sharp evagination of the otocyst extending toward the hind-brain is the *endolymphatic duct.* Ventral to the otocyst and between it and the hind-brain is the *acustico-facialis ganglion.* To the side of the hind-brain and almost between it and the fore-brain is the large *trigeminal ganglion.* Dorsal to the otocyst and to the side of the hind-brain is the *vagus ganglion.* Dorsal to the vagus ganglion may be seen fibers of the *spinal accessory* nerve.

Draw the section, color the germ-layers, and label all the parts.

(2) Through the Choroid Fissure and the Optic Stalk

This section passes through the fore-brain and the spinal cord. The spinal cord has differentiated into two distinct zones, the *dorsal zone* and the *ventral zone.* From either side of the spinal cord may be seen the roots of the *spinal nerves.* The *notochord* is small compared with the notochord of the chicken. Identify the *jugular*

vein on either side of the body ventral to the spinal cord. Near the jugular vein is the united *vagus* and *spinal accessory nerve*. Ventral to this nerve and also near the jugular vein is the *petrosal ganglion* of the ninth nerve. Identify the *gill clefts* and *gill arches*, the *carotid artery*, the *pharynx*, the *optic stalk*, the two layers of the *retina*, the *choroid fissure*, the *lens*, the *cerebral hemispheres*. Ventral to the first gill cleft is the *maxillary nerve*.

Draw the section, color the germ layers, and label all the parts.

(3) Through the Middle of the Heart and the Fore-limb Buds

The description of the spinal cord as given in section (2) will apply here also. At the origin of the limb bud is a nerve plexus, the *brachial plexus*. Dorsal to the brachial plexus is a blood vessel, the *subclavian vein*. Ventral to the notochord and on either side of the median line of the body is the *dorsal aorta*. Between the two dorsal aortæ and a little ventral to them is the *œsophagus*. Ventral to the œsophagus is the *trachea*. Ventral to the limb buds and on either side of the trachea is a large irregular blood vessel, the *duct of Cuvier*. The heart is now divided into four chambers, the two *auricles* and the two *ventricles*. The walls of the ventricles have become thickened and now have some of the characteristics of heart tissue. The tissue between the two ventricles is the *ventricular septum*. The triangular pieces of tissue extending from the dorsal wall of each ventricle down into the cavity of the ventricle are the *auricular-ventricular valves*. The cavities of the auricles are larger than

the cavities of the ventricles but the walls are very much thinner. The two auricles are separated dorsally by a thin membrane, the *septum spurium*. They are separated ventrally by a thicker membrane, the continuation of the ventricular septum.

Draw the section, color the germ layers, and label all the parts.

(4) Through the Body about Half Way between the Fore-limb Buds and the Hind-limb Buds

This section passes through the umbilical cord. The description of the spinal cord given in section (2) will apply here. The dorsal aorta is a single vessel in this region. On either side of the dorsal aorta is a large body filled with holes. These bodies are the Wolffian bodies. The part of the digestive tract in this region is the *stomach*. It is connected to the body dorsally by a neck of mesoderm, the *major omentum*. The mesoderm continuing from the stomach ventrally is the *minor omentum*. Surrounding the stomach laterally and ventrally are four large lobes of tissue filled with holes. These masses of tissue are the lobes of the liver. The large blood vessel in the right dorsal lobe is the *inferior vena cava*. The large blood vessels in the ventral lobes are the *umbilical veins*. In the tissue between the liver lobes is a hole surrounded by a thickened wall, the gall-bladder. Identify the *umbilical arteries* in the umbilical cord. On the ventro-median surface of the Wolffian body, near the dorsal end of the major omentum, is a ridge, the *genital ridge*.

Draw the section, color the germ layers and label all the parts.

2. The Pregnant Uterus

Uteri containing embryos three or four inches in length may be obtained from any large slaughter house. The whole uterus with the ovaries should be secured. If they are preserved and hardened for a few days in ten per cent. formalin, then transferred to three or four per cent. formalin, and finally soaked in water three or four days before using, they will be well preserved and most of the disagreeableness of the formalin preservatives will be removed. It is well to change the water some two or three times.

Examine the uterus and note that it is composed of two rather large tubes united at one end and free at the other. These are called the *horns of the uterus*. The horns are united at the *vagina*. Along the inner edge of each horn is a broad, tough, flat membrane which causes the outer edge to form a ruffle. This membrane is the *broad ligament*. The location of the embryos in the uterus is indicated by the enlargements. Note the many branched blood vessels beneath the surface of these enlargements. Trace one horn of the uterus to the free end. It will be seen that the horn suddenly narrows down into a tube that is about the size of a large knitting needle. This tube is the *Fallopian tube or oviduct*. The Fallopian tube ends distally in a thin membrane which surrounds the ovary, with the exception of an opening into the body cavity. This terminal opening is the *ostium tubæ ab-*

dominale. What is the size of the ovary? Shape? The large, colored irregularities of the ovary are the recent *corpora lutea*. How many in each ovary? How does the number compare with the number of embryos in the uterus? The smaller, rounded spots that resemble blisters are *Graafian follicles*. Open one of the Graafian follicles. What is the nature of the contents?

With a pair of scissors or scalpel remove one of the enlargements by cutting mid-way between two of them. Cut through the broad ligament. Open this part of the uterus by cutting longitudinally the side opposite the broad ligament. This cut should pass through the walls of the uterus and the outer embryonic covering, the *chorion*. In the pig, the chorion is composed of the chorion proper and the wall of the *allantois*. From one side carefully separate the chorion from the walls of the uterus. Note that the inner layer of the uterine wall is in folds which extend around the embryo. Also note the blood vessels in this layer. What is the position of the chorion with reference to these folds? Carefully separate the chorion from the amnion. The amnion is semi-transparent and is a much thinner membrane than the chorion. Note the blood vessels in the chorion. (The blood vessels are in the allantoic wall of the chorion.) Compare them with the blood vessels of the lining of the uterus. Also note the very small blood vessels of the amnion. To the ventral side of the embryo is the *umbilical cord*, which connects the embryo to the chorion.

Draw the embryo in position, showing the blood vessels

and connection of the embryo to the chorion. Label all the parts.

Carefully remove the entire chorion from the uterus. It will be seen that the only connection of the embryo to the uterus is the contact of the chorion and the mucous lining of the uterus. Open the amnion on the dorsal side of the embryo. It will be seen that it is not connected with the embryo except at the distal end of the umbilical cord. How many blood vessels in the umbilical cord? The blood vessels may be distinguished from the remainder of the tissue in the umbilical cord by their dark color, due to the blood in them. The colorless tube in the umbilicus is the *allantois*.

3. The Dissection of the Embryo

a. The Abdomen

Cut away the amnion and the chorion except for a small part at the end of the umbilicus. Open the embryo in the mid-ventral line, being careful to separate the tissue from the umbilicus. Do not break any of the blood vessels or the allantois. Pin back the body wall. The large, reddish-brown mass exposed is the *liver*. Separate the blood vessels in the umbilicus and trace them into the body. The one going to the liver is the *umbilical vein*. The other two are the *umbilical arteries*. Trace the allantois toward the posterior end. The enlargement of the allantois in the pelvic region is the *urinary bladder*. A tube from either side enters the bladder on the dorsal surface near the posterior end. These are the *ureters*. Separate the tube leading from the bladder

to the outside of the body. This is the *urethra.* Without removing any of the liver, examine it. Of how many lobes it is composed? Size? Position? Dorsal to the liver and a little posterior to it is the much coiled *intestine.* Dorsal to the bladder and ventral to the ureters are two fine tubes, one on either side, which unite dorsal to the posterior end of the bladder. These tubes are the *Fallopian tubes* in the female or the *vas deferens* in the male. The posterior part of the Fallopian tubes forms the horns of the uterus, which unite near the *vagina.* The point of union of the vas deferens forms the *sinus pocularis*, or male uterus. Trace the *sex ducts* until they open to the exterior. Near the anterior end of the sex ducts and a little ventral to them are the sex glands, the *ovaries* if female, or the *testes* if male. Dorsal to the sex glands and toward the median line of the body are the remains of the *Wolffian bodies.* By lifting the intestine and the posterior part of the liver, a part of the comparatively large *kidneys* may be seen. Trace the ureters to the kidneys. In the median line of the body, extending between the sex ducts and posteriorly dorsal to the urethra, is the posterior end of the intestine, the *descending colon* and the *rectum.*

Draw the dissection and label all the parts.

Trace the umbilical vein through the liver by carefully dissecting away a small part of the liver at a time. Immediately dorsal to the anterior part of the liver is the stomach. What is its shape? Position? The small bladder found in the liver is the *gall bladder.* The duct leading from the gall bladder is the *cystic duct.* This

unites with another small duct, the *hepatic duct*, to form the *common bile duct*. The common bile duct empties into the intestine a short distance posterior to the pyloric end of the stomach. Lying along the greater curvature of the stomach is a dark-colored body, the *spleen*. How is it held in position? Dorsal to the stomach is a whitish body, the *pancreas*. What is its shape? Position? A duct leads from the pancreas to the intestine. This is the *pancreatic duct*, or the *duct of Wirsung*. It empties into the intestine near the place where the common bile duct empties into the intestine. How is the intestine held in position? The connective tissue that holds the intestine in position is the *mesentery*. Carefully remove the mesentery and straighten out the intestine. Is it a continuous tube? How long is it? What marks the transition from the large to the small intestine? Is there a difference in size between the large and the small intestine? In length?

Trace the umbilical arteries to their origin. They are branches of the dorsal *aorta*. A short distance from the aorta the umbilical arteries branch, one part going to the umbilicus and the other going to the hind leg. The one going to the hind leg is the *iliac artery*. A short distance posterior to the origin of the umbilical arteries the aorta divides into two parts. These are the *caudal aortæ*. Trace the aorta to the *diaphragm*. Note the branches given off to the kidneys, *renal arteries;* to the mesentery, *superior mesenteric artery;* to the liver, *hepatic artery;* and to the stomach, the *gastric artery*.

Dorsal to the iliac arteries are the *iliac veins*. They

unite to form the ascending *vena cava*. From the kidneys, ventral to the renal arteries, the ascending vena cava receives the *renal veins*. Trace the ascending vena cava to the diaphragm. How does the blood from the umbilical vein get into it? Where does the blood from the intestine go?

Draw a diagram of the circulation thus far worked out and label all the parts.

b. **The Thorax**

What blood vessels pass through the diaphragm? The œsophagus extends from the stomach through the diaphragm into the thorax. Separate the diaphragm from the body wall. The masses of tissue occupying the greater part of the thoracic cavity are the lungs. How many lobes? Size? Shape? Position?

What is the position of the heart? Size? Shape? The heart is enclosed in a thin connective tissue sac, the *pericardium*. The point of the heart is called the *apex* and the other end is called the *base*. The firm, muscular part of the heart composes the *ventricles* and the darker colored, softer portion at the base composes the *auricles*. Both the auricles and ventricles are called right and left, according to their position. Trace the aorta to the heart. Where does it enter the heart? How many arches has the aorta now? The artery leading from the ventricle to the lungs is the *pulmonary artery*. Which ventricle? What is the relation of the pulmonary artery to the lungs? From the anterior part of the arch of the aorta arises a vessel which carries the

blood toward the head. This vessel is the *innominate artery*. Branches from the innominate artery are given off laterally, going to each fore-limb, the *right* and *left subclavian* arteries. Do you find the *carotid arteries* leading from the innominate artery to either side of the head? Trace the inferior vena cava vein to the heart. With what part of the heart does it connect? The *superior vena cava* and the inferior vena cava empty into the heart near the same place. The blood from the anterior part of the body is collected in the superior vena cava. Trace it and its branches to the neck and fore-legs. Do you find the *pulmonary veins?* The pulmonary veins carry the blood from the lungs to the heart. What part of the heart? Open the heart. Describe the valves separating the auricles from the ventricles. The two ventricles are separated by a muscular wall, the *ventricular septum*. The two auricles are not separated. The opening between the two auricles is the *foramen ovale*. Is there any trace of the formation of the *auricular septum?*

Draw a diagram of the circulatory system in the thorax as you have found it in your dissection. Label all the parts.

Trace the lungs to the mouth. Trace the œsophagus to the mouth. What is the relation of the œsophagus to the trachea and larynx?

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